Peremennye Zvezdy **27**, No.4, 2007
Variable Stars **27**, No.4, 2007

SAI, INASAN, Astronet.ru
Moscow, Russia
3 October 2007

PHOTOMETRIC OBSERVATIONS OF SUPERNOVA 2002hh

D. YU. TSVETKOV[1], M. M. MUMINOV[2], O. A. BURKHANOV[2], B. B. KAHHAROV[2]

[1] Sternberg Astronomical Institute, University Ave.13, 119992 Moscow, Russia; e-mail: tsvetkov@sai.msu.su

[2] Ulugh Bek Astronomical Institute of Uzbekistan Academy of Sciences

Abstract

CCD VRI photometry is presented for SN 2002hh from 14 days after the outburst till day 347. SN 2002hh appears to be normal type IIP supernova regarding both luminosity and the shape of the light curve, which is similar to SN 1999gi.

SN 2002hh was discovered on 2002 October 31.1 UT during the course of the Lick Observatory Supernova Search (Li, 2002). SN is located at $\alpha = 20^{\rm h}34^{\rm m}44^{\rm s}.29, \delta = +60°07'19''.0$ (2000.0), which is $60''.9$ west and $114''.1$ south of the nucleus of Scd galaxy NGC 6946, which has produced 7 other SNe. Spectra taken by Filippenko et al. (2002) on 2002 November 2 revealed it to be a very young, highly reddened type II SN. Broad, low-contrast Hα emission and absorption lines as well as strong, narrow interstellar Na I D absorption were present. The continuum was nearly featureless and very red. SN 2002hh was also detected as a source of radio and X-ray emission (Stockdale et al., 2002; Pooley and Lewin, 2002).

A detailed study of optical and infrared photometric and spectroscopic evolution for this object was presented by Pozzo et al. (2006). They concluded that SN 2002hh was a SN IIP (plateau), with early light curve similar to SN IIP 1999em, and that radioactive tails are well matched for these two SNe and SN 1987A. They adopted two-component model for extinction with total $A_V = 5.2$ mag.

We observed SN 2002hh from 2002 November 13 until 2003 October 12 with different telescopes and detectors: 60-cm reflector of Crimean Observatory of Sternberg Astronomical Institute (C60) equipped with SBIG ST-7 CCD camera; 70-cm reflector in Moscow (M70) with Meade Pictor416XT camera (a) or Apogee AP47 camera (b); 1.5-m reflector of Maidanak Observatory (Md150) with SITe 2000x800 LN cooled CCD camera.

The image of SN 2002hh obtained at Md150 on 2003 August 10 in the I band is shown in Fig. 1, where the local standard stars are marked. The magnitudes of these stars were measured on 11 photometric nights mostly in 2004-2005, when observations of SN 2004et in the same galaxy were carried out, they are reported in Table 1. VRI magnitudes of these stars were derived also by Pozzo et al. (2006), and the mean differences between two data sets and their dispersions are: $\overline{\Delta V} = 0.015; \sigma_{\Delta V} = 0.01; \overline{\Delta R} = -0.008; \sigma_{\Delta R} = 0.01; \overline{\Delta I} = 0.053; \sigma_{\Delta I} = 0.027$. We may conclude that the agreement is good. Photometric measurements of SN were made relative to local standard stars using PSF-fitting with IRAF† DAOPHOT package. On the nights with bad seeing the images of SN and nearby

†IRAF is distributed by the National Optical Astronomy Observatory, which is operated by AURA under cooperative agreement with the National Science Foundation

bright star overlayed, and it was necessary to subtract the image of this star using task SUBSTAR in DAOPHOT.

The color terms for transformation of instrumental magnitudes vri to standard $VRcIc$ were derived from observations of standard fields for C60 and M70 and by photometry of local standards for Md150. The resulting color terms are $K_v = -0.007; K_r = -0.48; K_i = -0.27$ for C60; $K_r = -0.35; K_i = -0.31$ for M70a; $K_r = -0.46; K_i = -0.37$ for M70b; $K_r = 0.12; K_i = 0.0$ for Md150.

The photometry of SN 2002hh is presented in Table 2, and the light curves are shown in Fig. 2, where the data from Pozzo et al. (2006) and magnitude estimates at discovery and prediscovery upper limit from Li (2002) are also plotted. At the plateau stage the agreement between the two data sets is quite good, although our R and I filters at C60 and M70 do not match the standard system well. Only in the I band there is evidence for some systematic difference, our magnitudes being about 0.15 mag brighter.

We obtained images on two dates (2003 March 3 and March 26) which are in the gap of Pozzo et al. (2006) data. At the exponential decline stage our I magnitudes from Md150 are in very good agreement with the results of Pozzo et al. (2006), while in the R band our magnitudes are systematically brighter by about 0.18 mag. This difference is likely due to different response curves of the equipment applied to the object with very red color and emission-dominated spectrum. This is also the reason for our magnitudes from M70 to be brighter than from Md150; the later should be given greater weight as their errors are smaller and the color system closer to standard.

We estimated the rate of decline at the exponential tail by fitting straight line to the data from Md150: 0.0073 ± 0.0003 mag day^{-1} in R and 0.0094 ± 0.0004 mag day^{-1} in I. The result for I band is close to that by Pozzo et al. (2006), but in R they found significantly larger rate: 0.011 mag day^{-1}. We suppose that the difference is due to larger errors of magnitudes by Pozzo et al. (2006) at late stage. We can also estimate the drop of brightness from the plateau to the onset of exponential tail: 1.4 mag in R and 1.6 mag in I.

We found that the light curve of SN 1999em was not a good match to the data for SN 2002hh, as the brightness decline between the plateau and the onset of exponential tail was significantly smaller for SN 2002hh. Among the well studied SN IIP with normal luminosity SN 1999gi was probably the best match, although considerable differences can be seen on Fig. 2, where we plotted the light curves of SN 1999gi according to Leonard et al. (2002) and our own unpublished data. While in the I band the match is very good, in R and V the magnitude difference between plateau and the onset of final decline is greater for SN 1999gi.

Taking the extinction from Pozzo et al. (2006) and a host galaxy distance of 5.9 Mpc (Karachentsev et al. 2000), we obtain absolute magnitude at maximum light $M_V = -16.7$, close to the mean value for SN IIP (Richardson et al., 2002).

We conclude that SN 2002hh is a normal type IIP supernova, with the light curve similar to SN 1999gi, especially in the I band. Our photometry confirms the results of Pozzo et al. (2006), but we obtain slightly different magnitudes and rate of decline in the R band at the epoch 200-340 days past explosion.

The work of D.Yu.Tsvetkov was partly supported by the grant 05-02-17480 of the Russian Foundation for Basic Research.

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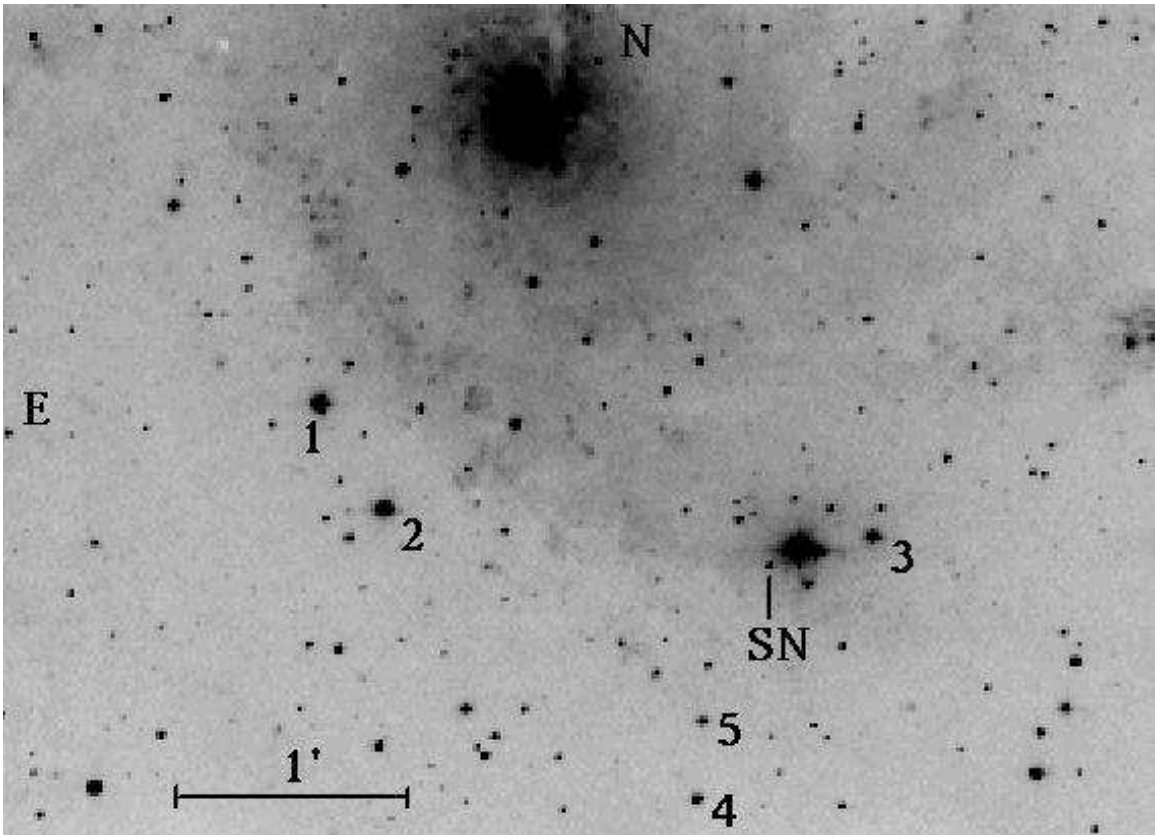

Figure 1. SN 2002hh and local standard stars

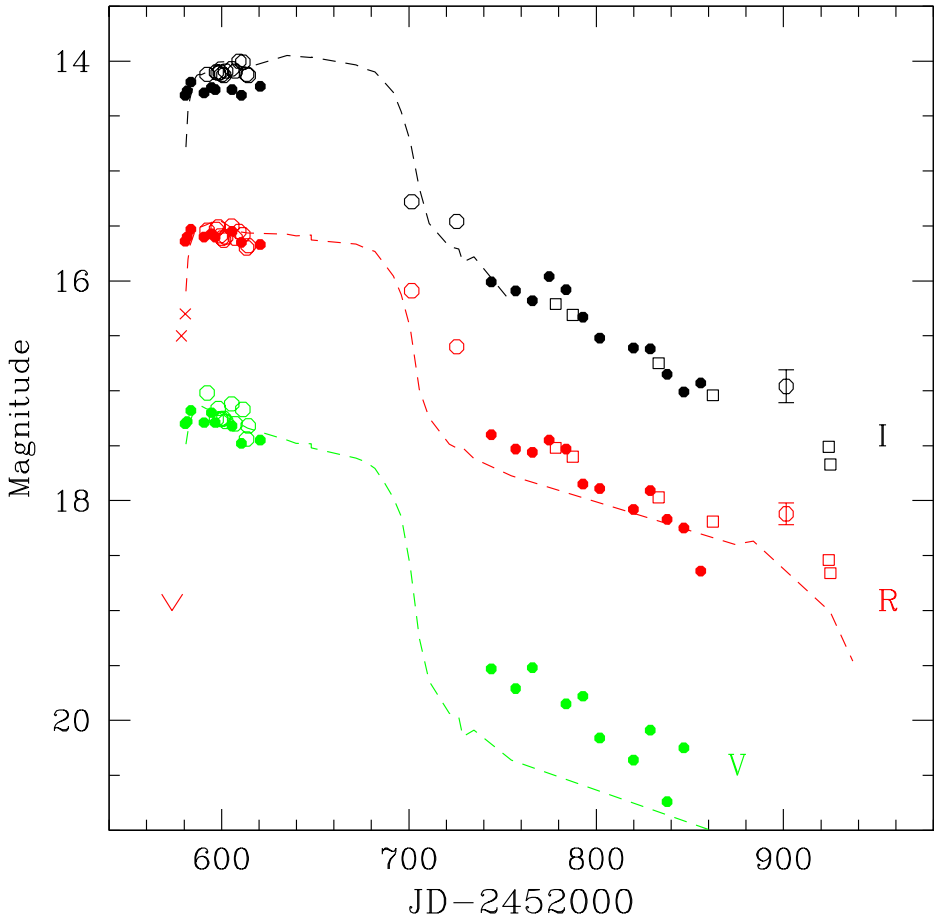

Figure 2.

VRI light curves of SN 2002hh. Circles show our data from C60 and M70, squares are for our data from Md150, dots show photometry by Pozzo et al. (2006), crosses and 'v' mark are for discovery estimates and prediscovery limit by Li (2002). Error bars for our magnitudes are plotted only when they exceed the size of a point. The dashed lines are the light curves of SN 1999gi

Table 1: Magnitudes of local standard stars

Star	U	σ_U	B	σ_B	V	σ_V	R	σ_R	I	σ_I
1	14.60	0.08	14.30	0.01	13.56	0.01	13.14	0.03	12.75	0.02
2	14.78	0.03	14.51	0.02	13.77	0.01	13.35	0.03	12.96	0.02
3	15.92	0.03	15.59	0.03	14.76	0.01	14.22	0.04	13.85	0.03
4			16.62	0.05	15.86	0.01	15.35	0.04	15.00	0.03
5			17.58	0.05	16.46	0.06	15.74	0.04	15.17	0.02

Table 2: Photometry of SN 2002hh

JD 2452000+	V	σ_V	R	σ_R	I	σ_I	Tel.
592.31	17.02	0.07	15.54	0.03	14.12	0.03	C60
597.21	17.26	0.06	15.53	0.07	14.10	0.04	C60
598.23	17.16	0.05	15.51	0.04	14.11	0.04	C60
599.24	17.26	0.05	15.59	0.04	14.10	0.04	C60
600.20	17.26	0.05	15.61	0.05	14.12	0.04	C60
601.17	17.25	0.08	15.63	0.05	14.13	0.07	C60
602.18	17.28	0.05	15.60	0.03	14.09	0.03	C60
605.38	17.12	0.09	15.50	0.04	14.07	0.04	C60
607.26	17.30	0.08	15.61	0.05	14.09	0.05	C60
609.32			15.55	0.04	14.00	0.05	C60
611.38	17.17	0.07	15.58	0.04	14.01	0.07	C60
613.39	17.44	0.05	15.70	0.03	14.12	0.03	C60
614.27	17.32	0.07	15.68	0.05	14.13	0.04	C60
701.50			16.09	0.05	15.28	0.04	M70a
725.54			16.60	0.07	15.46	0.04	M70a
778.44			17.52	0.03	16.21	0.02	Md150
787.46			17.60	0.03	16.31	0.02	Md150
833.38			17.97	0.04	16.75	0.02	Md150
862.27			18.19	0.03	17.04	0.02	Md150
901.44			18.12	0.11	16.96	0.16	M70b
924.13			18.54	0.03	17.51	0.02	Md150
925.10			18.66	0.03	17.67	0.02	Md150